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RESEARCH

Woodland Dynamics as a Result of Settlement Relocation on Pleistocene Sandy Soils in the Netherlands (200 BC–AD 1400)

Bert Groenewoudt* and Theo Spek†

In this paper we investigate the potential of charcoal kilns as indicators (proxy data) of the interaction between settlement dynamics and the history of woodland presence, composition and structure. The results demonstrate that in our research area (Pleistocene sandy soils of the Netherlands) woodland regeneration and deforestation can be traced by a careful examination of the archaeological remains from charcoal production, provided such remains are systematically recorded, contextualized and subjected to meticulous dating, preferably ¹⁴C dating. Remains of charcoal kilns are also a useful source of information when attempting to reconstruct the occurrence and location (borders) of former woodlands. Optimum results are achieved for this purpose if charcoal kiln research is an integral part of an interdisciplinary landscape-historical approach. Woodland regeneration on abandoned fields as demonstrated by the presence of charcoal kilns seems to have been common for a long time, and it was not unusual for this to occur several times at the same site. Woodland 'mobility' and change as defined in this paper was brought about by a complex combination of three different types of settlement relocation: 1. expansion-contraction (periodic); 2. systemic micro-mobility (structural); 3. macro-mobility (incidental).

Keywords: charcoal production; charcoal kilns; settlement relocation; deforestation; woodland regeneration; woodland history

Introduction

Throughout the world woodlands have been an intrinsic element of cultural landscapes since early prehistoric times. The history of primeval and secondary woodlands has been closely intertwined with the economic, social and cultural life of humans who lived in or near these woodlands (Seeland, 1977). As the long-term interactions between humans and nature have always been multiple and variable, they have resulted in constant changes in woodland composition and structure over time (Williams, 2000). In addition, long-term interference by humans in woodlands has not only left many human traces in woodlands themselves, it has also had significant impacts on soil chemistry, hydrology, erosion, vegetation and biodiversity. It is therefore important to identify anthropogenic woodland dynamics and to understand the driving forces behind them. Moreover, because human intervention has been part of the forest ecosystem for a very long time, the distinction between natural forest and cultural woodland

may not be very useful. Instead, both woodland research and management could profit from historical-ecological approaches integrating ecological and cultural data, as well methods and theories.

Although many scientists have published reviews of the long-term history and management of woodlands in Western Europe (e.g. Buis, 1985; Tack, van den Brecht and Hermij, 1993; Hasel and Schwarz, 2002; Küster, 1998; Peterken, 1993; Peterken, 1996; Rackham, 1980; Rackham, 1990), there is still a lack of interdisciplinary empirical studies on woodland history. In this paper, we present the results of interdisciplinary research exploring the information potential of archaeological remnants of charcoal production (charcoal kilns) in terms of landscape and woodland history. In particular, we aim to assess the value of charcoal kilns for the reconstruction of settlement and woodland mobility, and for establishing the consequences mobility may have had. To achieve this goal, we 1) briefly review relevant research on settlement and woodland history, 2) investigate the potential of charcoal kilns as indicators (proxy data) of the interaction between settlement dynamics and the history of woodland presence, composition and structure. Our dataset consists of well-dated charcoal kilns excavated on the Pleistocene sandy soils of the Netherlands (**Figure 1**). Two case studies will be presented: Zutphen-Looërenk and Anloo-Bosweg. We focus on the late prehistoric, early historical and

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Figure 1: Research area: the sandy soils of the Netherlands (yellow), forming part of the western section of the European aeolian sand belt (top-left; after Hilgers, 2007). The distribution of sites with well-dated pit kilns is indicated (black dots). Dates range from c. 200 BC to c. AD 1400. The case study sites described in the text are A: Anloo-Bosweg, B: Zutphen-Looërenk. Other sites referred to in the case studies are a: Almen-Asselerweg, b: Barneveld-Harselaar, d: Doetinchem-Lookwartier.

Medieval periods (BC 200–AD 1400). The data from our research area are interpreted within a wider context: the Pleistocene sandy landscapes of northwestern Europe also including western Jutland, northern Germany and the northwestern part of Belgium.

2. Earlier research

Woodland change

Pollen studies demonstrate that during the Atlantic (c. 6000–3000 BC) the elevated parts of the Pleistocene sandy soils of the Netherlands were covered by forest

composed of deciduous trees, mainly oak, lime, elm and hazel (see e.g. Bakker, 2003; Behre and Kucan, 1986; Odgaard, 1994; Spek, 2004), i.e. tree taxa that probably formed a mosaic of relatively homogeneous woodlands stands or ecosystems (Behre and Kucan, 1994). Which tree taxa were dominant depended on local soil conditions, particularly loaminess (percentage of soil particles smaller than 50 μm) and humidity. This Early Holocene woodland was never entirely pristine. Northwestern Europe was always populated to some extent during the Holocene, and woodlands were exposed to human influence, even

before the introduction of agriculture (e.g. Faegri, 1988; Odgaard, 1994; Williams, 2000). There is some evidence from the Netherlands (e.g. Bos et al., 2005; Bos and Zuidhoff, 2011; Kubiak-Martens et al., 2015) of deliberate clearance of certain areas within the forest as early as the Mesolithic period, probably mainly by controlled burning (Mellars, 1976).

During the Neolithic, and particularly from c. 3200–2700 BC onwards, human interference in the forest in the form of reclamation and woodland grazing intensified (Behre and Kucan, 1994; Iversen, 1941; Iversen, 1973). During the Late Bronze Age and Early Iron Age, in particular, deforestation and the expansion of agricultural land accelerated in many parts of northwestern Europe (e.g. Behre, 1976; Behre and Kucan, 1994; Bohncke et al., 1988; Bohncke, 1999; Casparie and Groenman van Waateringe, 1980; De Kort, 2007; Fyfe et al., 2013; Groenewoudt et al., 2007; Meurers-Balke and Kalis, 2005; Nielsen et al., 2012; Overland and O'Connell, 2008; Pratt, 1996; Rackham, 1980; Sohl, 1983; Spek, 2004; Trondman et al., 2015; Turner, 1970; Waller and Schofield, 2007). As a result woodland pastures are assumed to have been common in Bronze Age and Early Iron Age landscapes. These landscapes were probably semi-open in many parts of Europe, spatially dynamic and characterised by curvilinear shapes and fuzzy borders (e.g. Gimingham, 1975; Vera, 1997; Vera, 2000). We will show that these landscapes remained spatially dynamic until well into the Middle Ages on the Pleistocene sandy soils of the Netherlands. In densely populated areas, landscapes became more open (e.g. Fyfe et al., 2013; Trondman et al., 2015), and only isolated clumps of woodland might have survived, i.e. a predominantly wooded landscape with some small deforested/unforested areas (Early-Middle Holocene; e.g. Bradshaw et al., 2003; Svenning, 2002) transformed into an open landscape with small woodland areas (Middle-Late Holocene). This

open landscape looked very much like a 'reverse image' (Groenewoudt et al., 2007; **Figure 2**) of the 'original' (predominantly) densely wooded landscape (e.g. Bradshaw et al., 2003; Svenning, 2002). As far as our study area is concerned the wealth of new archaeological and archaeobotanical data that has become available since the Valletta Convention (1992) was incorporated into Dutch law has contributed significantly to this view (Groenewoudt et al., 2007; Spek, 2004).

The increase in deforestation is usually neither linear nor continuous over time. On the sandy soils of the Netherlands there is palynological and archaeological evidence, at both the regional and the local spatial scale, that in some periods the surface covered by woodland actually increased. Forest regeneration has been demonstrated for the early Roman period and especially for the period immediately following the Roman period, although not everywhere, and certainly not in all places to the same extent (Van Munster, 2012). Unlike the situation in the eastern Netherlands (Groenewoudt et al., 2007) and the central Dutch Veluwe area (Van Geel and Groenman-van Waateringe, 1987), where palynological evidence indicates that woodland regeneration was limited, large-scale post-Roman forest regeneration definitely occurred in the south of the Netherlands (Roymans and Gerritsen, 2002). Landscape archaeological research suggests that post-Roman woodland expansion in the southern Dutch Veldhoven area was followed by successive phases of deforestation (c. AD 850), reforestation (c. AD 950) and deforestation (c. AD 1100), after which the landscape remained open until the present (Theuws, 2011).

The many ways in which the woodlands on Northwest European Pleistocene sandy soils were exploited over several millennia had various short-term to long-term (even permanent) effects on the woodland ecosystems, and especially on soil degradation (e.g. Verheyen et al., 1999).

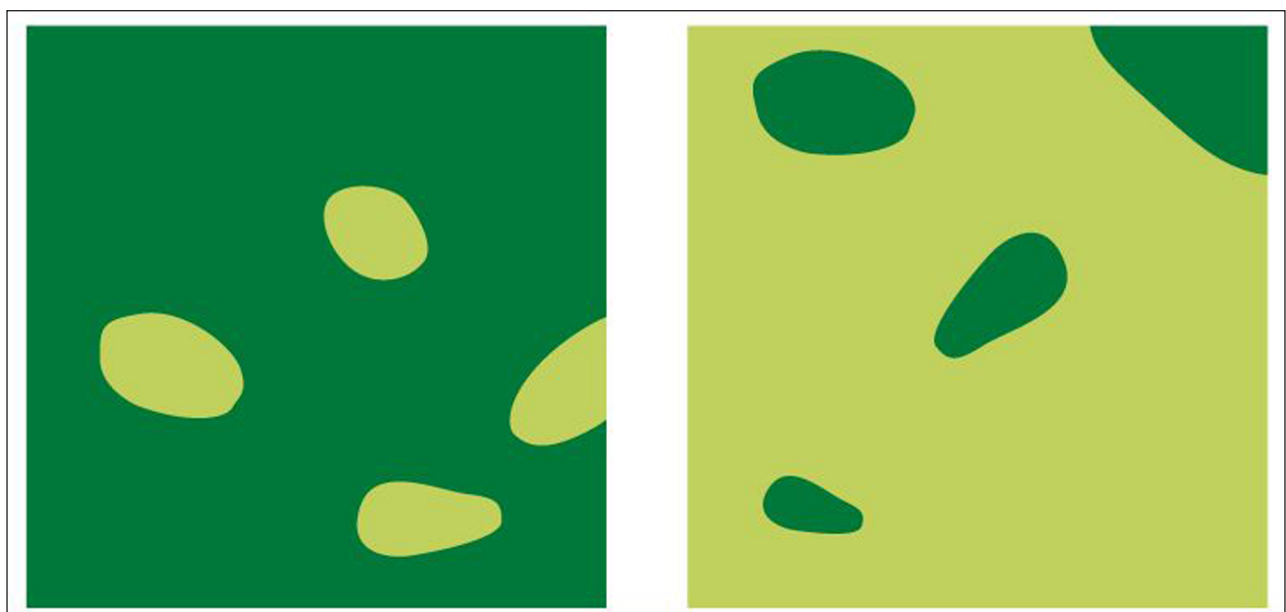


Figure 2: 'Reverse image' model of landscape transformation over time due to intensified land use. Densely wooded landscapes with isolated clearings transform into open landscapes with isolated clumps of woodland (almost becoming a reverse picture of the former landscape) (after Groenewoudt et al., 2007).

In the more elevated parts of the Pleistocene sandy areas, i.e. the focus area of the present study, deforestation rapidly altered the chemical properties of the soil, causing soil acidification and the accelerated leaching of nutrients (Spek, 1996; Stockmarr, 1975; see also Verheyen et al., 1999). Repeated deforestation had a lasting impact on soil fertility and vegetation (cf. Faegri et al., 1988; Seeland, 1997; Vanwallegghem et al., 2004; Verheyen et al., 1999; Williams, 2000) and it largely explains the composition of present-day (secondary) woodland. Such information is not only of landscape–historical and landscape–ecological interest; therefore, it is also needed for a proper understanding and good management of modern woodlands (cf. Peterken, 1993; Peterken 1996).

As a result of soil degradation in the sandy areas under consideration, secondary woodland was less dense than primeval woodland (e.g. Casparie and Groenman van Waateringe, 1980). This largely human-induced change also influenced biodiversity. It may for instance have resulted in a rather prominent presence of large herbivores (Louwe Kooijmans, 2012; Zeiler and Kooistra, 1998). Over the years, population growth and agricultural intensification increasingly suppressed natural reforestation processes. The dominant cause of deforestation and the emergence of open landscapes was probably not so much woodland clearance itself, but rather impeded woodland regeneration as a result of intensified land use.

Settlement mobility

Studies in the Netherlands have revealed that prehistoric agricultural settlements and fields shifted location from time to time (Schinkel, 2005; Waterbolk, 1991; Waterbolk, 1995). In the Dutch sandy areas the average distance over which settlements moved seems to have been around 300m (Theunissen, 1999; see also the discussion in Arnoldussen, 2008). This may have been triggered by soil exhaustion as well as social factors (Gerritsen, 2003). The frequency of shifting is difficult to estimate. Assuming that shifts coincided with the lifespan of houses, estimated at a maximum of 50 years (Zimmermann, 1998), settlements may have moved twice every century over the course of three or four millennia. Continuous movement would add up to at least 60 to 80 shifts. It is evident that the spatial dynamics of settlement influenced how intensively land was exploited. Previously settled, intensively exploited locations were abandoned and used extensively, if at all; ‘infields’ (settlements and arable land) gradually became ‘outfields’ (peripheral, unsettled areas) and vice versa. In the period under discussion, natural woodland regeneration on former fields and woodland mobility usually appear to have been caused by a change of location in the settlements’ ‘centres’ and ‘peripheries’, as Spek (2004) observed in the Dutch province of Drenthe. The process itself and the consequent successions of woodland clearance and woodland regeneration were probably repeated several times at the same locations. The final result of continuous settlement relocation was that virtually all agriculturally suitable land had been used as such, or had at least been deforested, at some point in time (see Kaplan et al., 2009, for an attempt to define ‘agricultural suitability’). The implication is that most, if

not all, spontaneously grown woodland in these areas is in fact secondary woodland.

The time at which this settlement mobility ceased, or at least slowed down significantly, varies from area to area. The first semi-permanent settlements in the Netherlands existed from the 2nd century AD, although mobility slightly increased again immediately after the Roman period (Van Beek, 2009). After the 9th–10th century AD settlement sites could still occasionally be abandoned (Van Beek, 2009) but no longer as a result of inherent systemic mobility. Such settlement abandonment was most common in peripheral or ‘marginal’ areas, where several successive phases of expansion and abandonment could alternate, as Lågeras (2006) has demonstrated for Sweden. A similar alternation of expansion and contraction phases can be observed in our research area (Groenewoudt and Scholte-Lubberink, 2007).

Interestingly, during this same period of long-term ‘micro-mobility’ there is also evidence of an episode of ‘macro-mobility’ (long-distance settlement shift). This shift occurred during the final centuries BC. The former settled lands were gradually abandoned and settlements shifted to (or became concentrated in) areas with more loamy soils, usually bordering low-lying land (Groenewoudt, 1989; Roymans 1991; Roymans and Theuws, 1999; Roymans and Gerritsen, 2002; Spek, 1993; Spek, 1996). Although these loamy soils were much more fertile than the sandy soils in the surrounding area, they were too densely wooded and too hard to cultivate until well into the Iron Age. It is assumed that gradual degradation of these woodlands by grazing and wood cutting over millennia made them more manageable from that time. Also, the improvement of ploughing equipment may have stimulated this settlement drift from sandy soils towards the more loamy soils in the Middle and Late Iron Age (4th–1st century BC), i.e. the shift may coincide with the earliest evidence of the use of the mouldboard plough (Agersnap Larsen, in press).

Ancient woodlands as a temporary landscape

The term ‘ancient woodland’ is used to describe woodland that is several centuries old (Hermý, 1994; Hermý et al., 1999; Peterken, 1977; Wulf, 1994). However, this denomination may suggest that such woodlands are remnants of truly ancient or primeval woodland. In many cases this has proven to be erroneous, as numerous settlement sites have been found in these woodlands. One striking example from the Netherlands is the presence of many late prehistoric field complexes (‘Celtic fields’) in woodland in the provinces of Drenthe, Gelderland and Utrecht that have been classified as ‘ancient woodlands’ (**Figure 3**; Kooistra and Maas, 2008; Neeffjes and Spek, 2014). Clearly, the woodlands covering these late-prehistoric Celtic fields are secondary woodlands that developed after the abandonment of the fields in the early Roman period (Spek et al., 2003). Furthermore, a palynological study of a soil profile in the Dutch Mantinger woodland revealed the following sequence of events: 1. Limited woodland clearance (c. 1050–900 BC); 2. Intense human interference: clearings, grazing etc. (c. AD 800–1000); 3. Large-scale woodland clearance during the 14th to 15th century

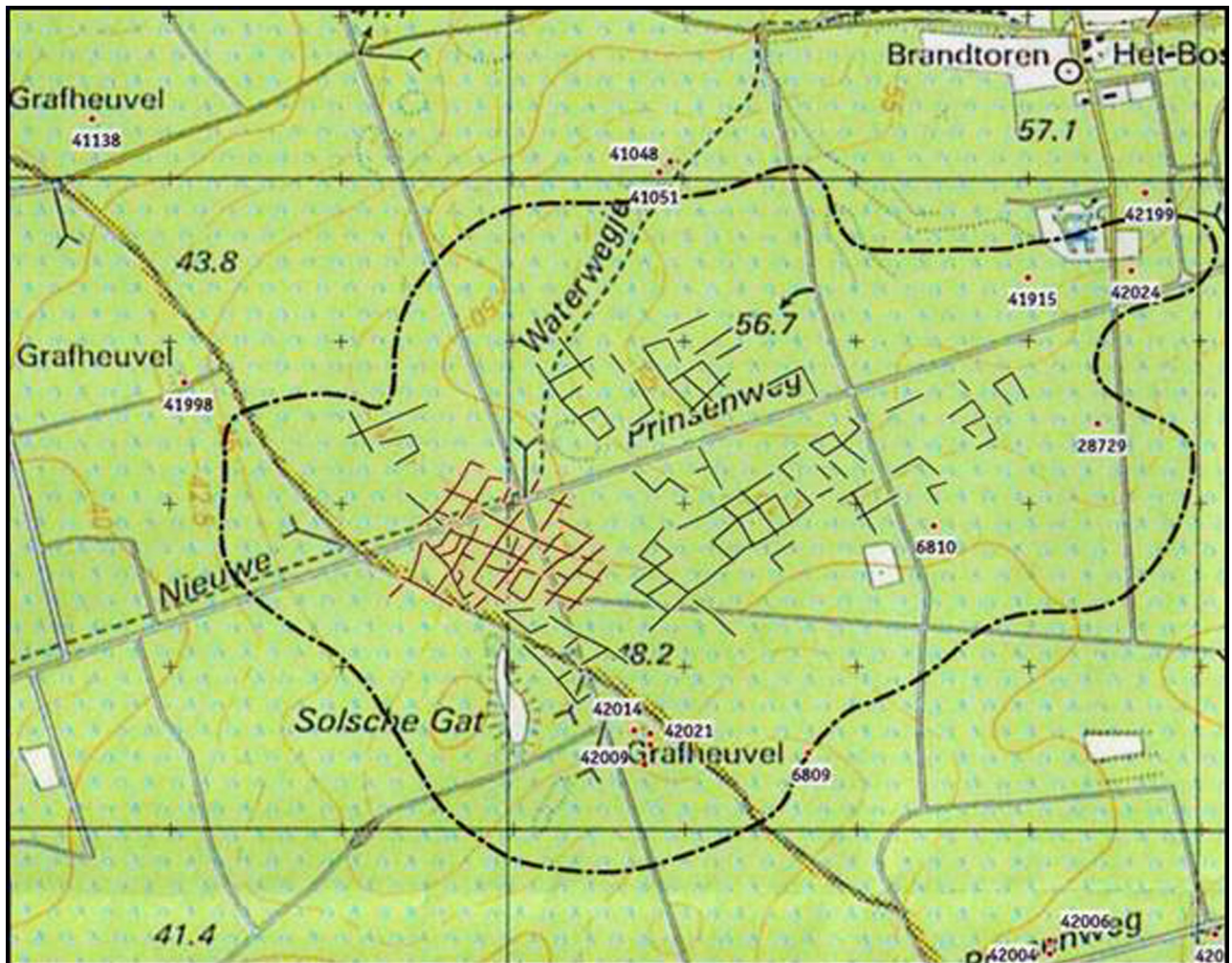


Figure 3: Traces of a late prehistoric field system of the Celtic Field type under ‘ancient woodland’ mapped on a recent topographical map, scale 1: 25.000. Speulder- en Sprielderbosch, Veluwe area, the Netherlands (after Willemse et al., 2008). Lines: field banks still recognisable. Dotted line: area with remains visible on LIDAR images.

(Stockmarr, 1975). Similarly, the nearby ‘ancient’ woodland of Amerholt barely existed during the Iron Age and Roman period, as shown by pollen records from these time periods (Spek et al., 2015: 254–255).

Similar examples of woodland growing today or in the late Middle Ages on land that was once partly cultivated or entirely deforested are available from neighbouring countries. Schreg (2007) and Rösch (2007) describe phases of woodland reclamation and abandonment in the German Black Forest. A good example of a large number of Celtic fields covered by ‘ancient’ woodland is the North German Sachsenwald (Arnold, 2011). In Denmark Iversen’s well-known studies of the Draved woodland revealed four phases of (partial) clearance between the Neolithic and the Viking Age (c. 10th century AD) (Iversen, 1969; Iversen, 1973). In Belgium, parts of the Meerdaal woodland were shown to be periodically treeless during the Bronze Age, Iron Age and Roman period (Baeté et al., 2009; Vanwallegghem et al., 2004), and Verheyen et al. (1999) discussed abandoned Medieval woodland reclamations at Enne (see also Tack, van den Brecht and Hermans, 1993). For British examples we refer to e.g. Rackham (1990), Scaife and Burrin (1983) (Weald area) and Foard (2001) (Rockingham Forest). Traces of gully erosion in woodlands throughout Western Europe

were associated with earlier episodes of disturbance in the woodland cover (Bork et al., 1998; Gullentops, 1992; Vanwallegghem et al., 2003; Vanwallegghem et al. 2006). Thus, evidence of spontaneous woodland regeneration on former agricultural land in Western Europe is widespread and irrefutable.

Charcoal burning

Charcoal production implies the presence of woodland. The amount of historical and ethnographical documentation in support of this assumption is overwhelming (e.g. Boeren et al., 2009; Bond, 2007; Lipsdorf, 2001; Ludemann, 2010; Ludemann, 2012; Raab et al., 2015; Rösler et al., 2012). Unlike tree pollen data, which reflects the occurrence of trees both locally and regionally (e.g. Behre and Kucan, 1986; Broström, 2002), the evidence of historical and prehistorical sites devoted to charcoal production implies the local presence of woodland at the site or very close to the site. Therefore, well-dated charcoal kilns provide high-resolution data on local woodland history. At sites where remains of previous settlement and agricultural activity are found, the charcoal kilns indicate woodland regeneration.

Many woodland areas that were exploited for the purpose of charcoal production have disappeared. Cases

where it has proved possible to reconstruct the former extent of woodlands that have largely or completely vanished are of particular interest. Such information may contribute to a detailed reconstruction of historical landscapes. One such study is an investigation of over

six hundred surface kilns from the 13th to 14th centuries recorded in parts of the area known as Rockingham Forest (UK) (Foard, 2001; see also Bond, 2007). The areas with kilns were converted into agricultural land between the 16th and 19th centuries (**Figure 4**). The hearths surfaced

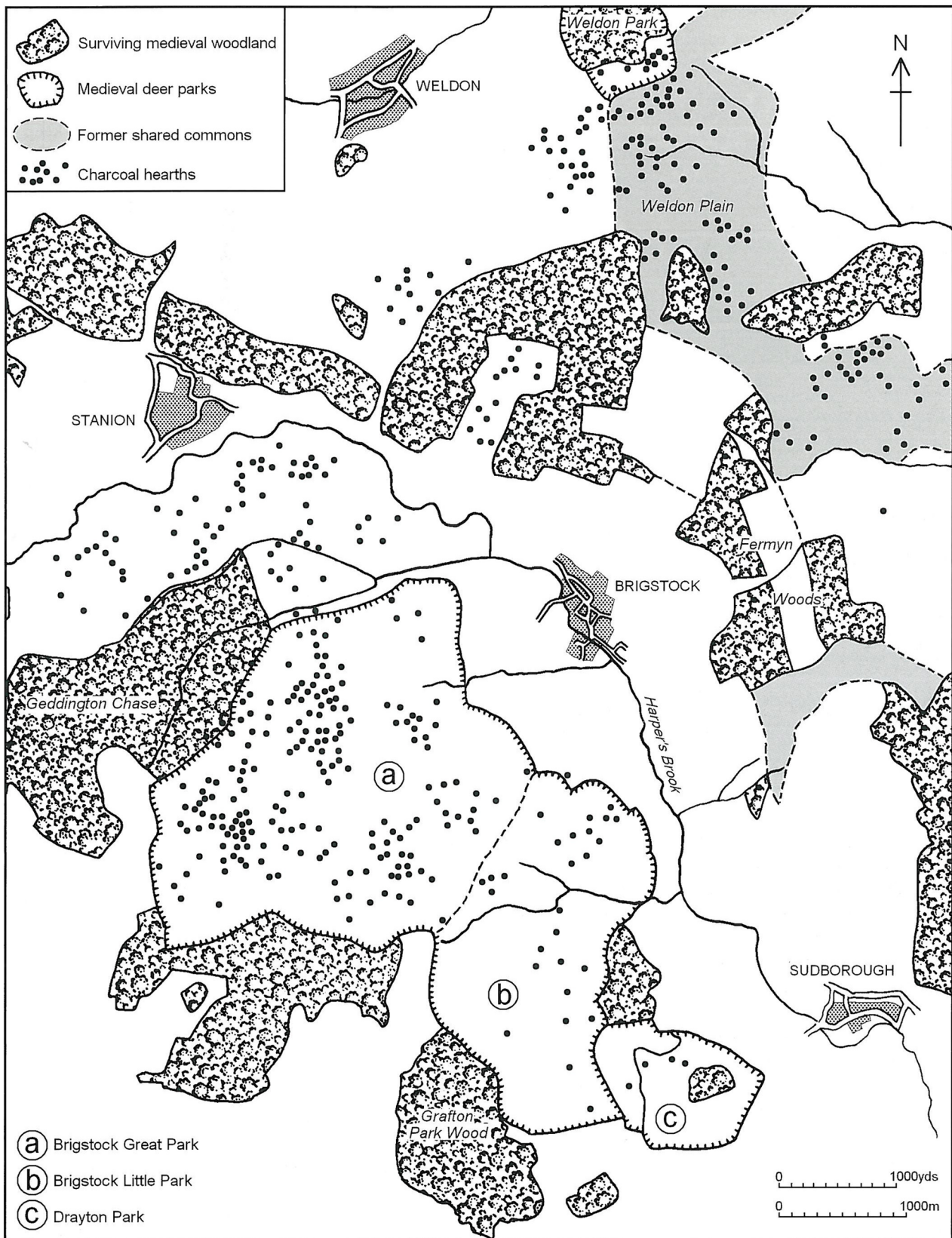


Figure 4: Distribution of charcoal hearths in Rockingham Forest (UK), allowing a detailed reconstruction of the woodland contours in the 13th to 14th centuries (after Foard, 2001).

when former grassland was being ploughed up. Another large pit kiln cluster was identified recently in the Veluwe area, Netherlands (Nieuwenhuize, 2012). These pit kilns are probably related to intensive iron production during the 8th century AD (Heidinga, 1987; Joosten, 2004).

In densely populated areas of northwestern Europe archaeological remains of charcoal kilns can be found in the few remaining ‘ancient’ woodlands as well as in cultivated areas. In woodland, features associated with charcoal production may still be visible on the surface and consist of remains of large surface kilns (charcoal clamps). They may take the form of artificial platforms erected against a slope, or of low mounds representing the remains of the clamp itself (e.g. Bond, 2007; Boeren et al., 2009; Lipsdorf, 2001; Ludemann, 2010; Ludemann, 2012; Raab et al., in press; Rösler et al., 2012). LIDAR (Laser Imaging Detection And Ranging) has proven very helpful in systematically mapping these kiln sites (Ludemann, 2012). In cultivated areas most evidence comes from archaeological excavations because ploughing has usually destroyed any remains of surface kilns, leaving only pit kilns (**Figure 5**). In general pit kilns predate surface kilns (Lipsdorf, 2001). Remains of pit kilns typically appear as relatively steep-walled, round or rectangular pits with a level floor, and walls that have turned red as a result of extreme heating. Their dimensions are fairly uniform: the diameter of round pit kilns usually varies from approx. 1.0 to 1.5 m, while

rectangular kilns measure approx. 1.0 m by 2.0 to 2.5 m. Their original depth was probably at least 0.6 to 0.7 m. In agricultural areas, remains of large charcoal clamps may also be identified from the air as darker, charcoal-rich concentrations in the fields (see e.g. Bond, 2007; Bond, 2007; NNU, 1999) and may even be visible at ground level in ploughed fields.

The palaeobotanical information gleaned from pit kilns appears to be limited. Unlike the infill of surface hearths (Deforce et al., 2012), that of pit kilns usually yields little palaeo-environmental evidence other than charcoal (De Man, 2002; Ter Wal, 1999; Van Smeerdijk et al., 2003). Opportunities for a detailed vegetation reconstruction are therefore limited.

3. Methods

In order to investigate the value of archaeological remnants of charcoal kilns for the reconstruction of settlement and woodland mobility in late prehistoric, early historic and Medieval times, we (i) analyse findings from well-dated charcoal kilns from the Pleistocene sandy landscapes of the Netherlands over the last few decades, including their archaeological context, (ii) analyse two case studies in more detail: Zutphen-Looërenk (eastern Netherlands) and Anloo-Bosweg (northern Netherlands), for which high-quality data are available, and (iii) interpret these data in terms of settlement and woodland mobility,



Figure 5: Archaeological remains of a pit kiln under excavation (site: Barneveld; after Brouwer, 2012).

as well as interactions between the two. Some charcoal kiln sites were discussed earlier (Groenewoudt, 2005; Groenewoudt, 2007). The data used come from basic, published excavation reports that present results of development-led archaeological excavations and only answer basic archaeological questions, as opposed to questions regarding (e.g.) the potential of charcoal kilns to provide landscape history information.

The spatial distribution of the studied kilns with reliable dates is shown in **Figure 1**. All data presented below derive from the Pleistocene inland regions of the Netherlands, and they are primarily from pit kilns. No archaeological remains of charcoal kilns are known from the low-lying Holocene coastal regions. The kilns were dated at 37 sites, either archaeologically (13.5%) or by ^{14}C dating of charcoal (86.5%). There is evidence that the material used for charcoal production was not always coppice wood of no more than approx. 15 years old, as was common practice in the Late Middle Ages and later (e.g. Lindsay, 1975; Rackham, 1990: 84); it could also be wood from trees that were up to a century old (Groenewoudt and Groothedde, 2008). Therefore, to obtain precise radiocarbon dates of charcoal kilns, it is preferable to use bark, twigs or seeds rather than charred wood. However, for practical reasons, it seems likely that young woodland consisting of trees with a limited age distribution was preferred. Both relatively young secondary woodland on former fields and coppiced woodland meet these criteria. In order to avoid dating older material of undetermined origin that may have ended up in the back-fill of the pit kiln, samples should be retrieved from dense concentrations of charcoal that can safely be interpreted as production debris.

4. Results and discussion

Charcoal kilns on the Pleistocene sandy soils of the Netherlands

In the area under consideration remains of pit kilns are frequently discovered during archaeological excavations, although their numbers vary greatly between the sites investigated. Whether or not this variation reflects any underlying cultural differences, or whether it is merely the result of differences in archaeological methodologies remains an open question. The dates from the kilns in our research area range from c. 200 BC to c. AD 1400 (Groenewoudt, 2005; Groenewoudt, 2007). The absence of any information on more recent periods is likely to be a result of the gradual introduction in the Late Middle Ages of above-ground charcoal kilns (Lipsdorf, 2001) that rarely left any traces in the Netherlands due to intensive agricultural land use. A large proportion of the pit kilns were dated to the 8th and 9th centuries. It has been suggested that this reflects large-scale charcoal production linked to the exploitation of newly established Frankish domains (Groenewoudt, 2007). A gap in the series of dates between c. AD 400 and AD 650 is of particular interest. It corresponds to the period immediately following the collapse of the Roman Empire. At that time, the Dutch areas were characterised by a substantial population decline, and some regions even became largely depopulated for a long time (Van Munster, 2012). As a consequence, charcoal pro-

duction (probably closely linked to iron production) either declined to a great extent or ceased completely.

The infill of excavated pit kilns rarely contains anything other than charcoal; other finds usually predate the kiln itself. This is a strong indication that the kiln remains represent the archaeological traces of *off-site* activity, which normally took place quite far from any settlement. Pit kilns discovered in the course of a settlement excavation are almost invariably either older or—more often—younger than the settlement remains (Groenewoudt, 2007). In situations where charcoal burning followed a phase of settlement and agriculture, the time lapse between the two types of land use was at least two centuries and usually considerably longer (see case studies below). Charcoal from pit kilns usually derives from only one species, in most cases oak. Although oak was a common species in the forests that were exploited, such exclusivity strongly suggests deliberate selection.

Pit kiln evidence from settlement excavations

Several Dutch sites have produced unequivocal evidence of woodland regeneration after a period of settlement and agriculture, i.e. after a phase of open or semi-open landscape. The data presented below come from reports of recent archaeological excavations (unless referencing indicates otherwise, interpretations are ours). A good example is the Budel-Noord site (Bink, 2012), where settlement remains from both the Roman period (1st–3rd centuries) and the Early Medieval period (6th–7th centuries) were excavated. Pit kilns from the 9th to 10th centuries were found in connection with the settlement features from both periods. They were aligned, as if following the edge of a woodland. At the Barneveld-Harselaar site (Brouwer, 2012), settlement traces from the Mesolithic and Neolithic periods (c. 2450–2000 BC), Bronze Age (c. 1800–1100 BC), and Iron Age (c. 250–12 BC) were excavated. A series of charcoal kilns excavated at the same site were dated to the 11th–12th century AD. Most of the pit kiln clusters were situated approx. 20 to 25 m apart in a northwest to southeast line. Analysed charcoal samples from the kilns were composed exclusively of oak. A site near Bennekom (De Leeuwe, 2008) revealed settlement remains from c. 1500 to 500 BC and several pit kilns from at least two distinct periods, the 1st century BC to the 1st century AD and the 11th–12th century AD. Yet another site, Meerhoven-Heistraat (Arts, 2013), contained settlement traces from the Mesolithic, Neolithic, Bronze Age, Iron Age and Roman period accompanied by charcoal kilns from two distinct periods, the 2nd–1st century BC and the 14th century AD. The Meerhoven-Heistraat site is situated near a hamlet first mentioned in 1389; the excavated settlement traces go back to the 13th century, however. The Eindhoven-Mispelhoef site (Arts, in press) revealed pit kilns from the 14th century situated within a small cemetery from the Roman period (1st–3rd century AD). Along the river Meuse at the Maasbree-Siberië site (Van Renswoude and Schuurmans, 2012), the site of another cemetery from the Roman period contained traces of a short-lived settlement from the 5th to 6th century as well as several pit kilns from the 7th to 8th centuries. Extensive

archaeological excavations near Lomm (Gerrets and De Leeuwe, 2011), again along the river Meuse, revealed settlement traces from the Iron Age and Roman period. The dates of the pit kilns at that site range from the 8th to the 13th century. In our opinion the low kiln density, as well as the temporal dispersion of their dates suggest that charcoal production was only an incidental activity at this site.

Case study at Zutphen-Looërenk (eastern Netherlands)

At the Zutphen-Looërenk site there is evidence of an entire woodland that was felled and reduced to charcoal within a relatively short period. This site was settled and characterised by agricultural land use for approx. 2000 years before it was abandoned in c. AD 0. A dense concentration of several hundred pit kilns was excavated at the site, most of them dated to the 9th century (Groenewoudt, 2006; Groenewoudt and Groothedde, 2008). The exploited woodland consisted of relatively mature trees, and all analysed charcoal was identified as oak. The extent of the cluster and the density of the pit kilns suggest that all available wood was used up. The distribution pattern even seems to provide some information on the location of the large oak trees in this Early Medieval forest. Archaeobotanical data indicate that, by the time charcoal production ceased, the landscape was largely deforested. Man-made watering holes associated with numerous hoof prints of cattle, both preserved in a natural depression, suggest that the site was briefly used as pasture land (Groenewoudt, 2006; Groenewoudt and Groothedde, 2008). The development of grassy

patches amidst the remnants of the woodland would certainly have made the location suitable for further grazing, and this activity may have contributed to the total disappearance of the forest. By the 10th or 11th century the site was reconverted into agricultural land. The dates of the pit kilns and the age of the archaeological material systematically recovered from the Medieval plough soil helped to reconstruct how these Medieval reclamations proceeded (Figure 6). Interestingly, they started at the site that was last inhabited (just before AD 0). After abandonment, the settlement site was probably never totally reforested, because it was used for pasture. The open space (bordered by remnants of a badger sett) must have been an obvious starting point for reclamation.

The study of the Zutphen-Looërenk site provides the best evidence of the temporal sequence of different land uses at the same site. However, there are similar indications from other sites (Figure 1), although the chronological resolution of the available data is insufficient to state unequivocally that charcoal production was a deliberate component of the reclamation process.

A reclamation phase starting from the 8th century was preceded by charcoal production dating to the late 7th or early 8th century AD at the nearby Doetinchem-Lookwartier site (Pronk, 2010). Archaeobotanical analysis revealed that these processes coincided with large-scale deforestation; by the 9th–10th century the elevated parts of the surrounding landscape were largely treeless. At the Barneveld site, charcoal production also seems to have been followed

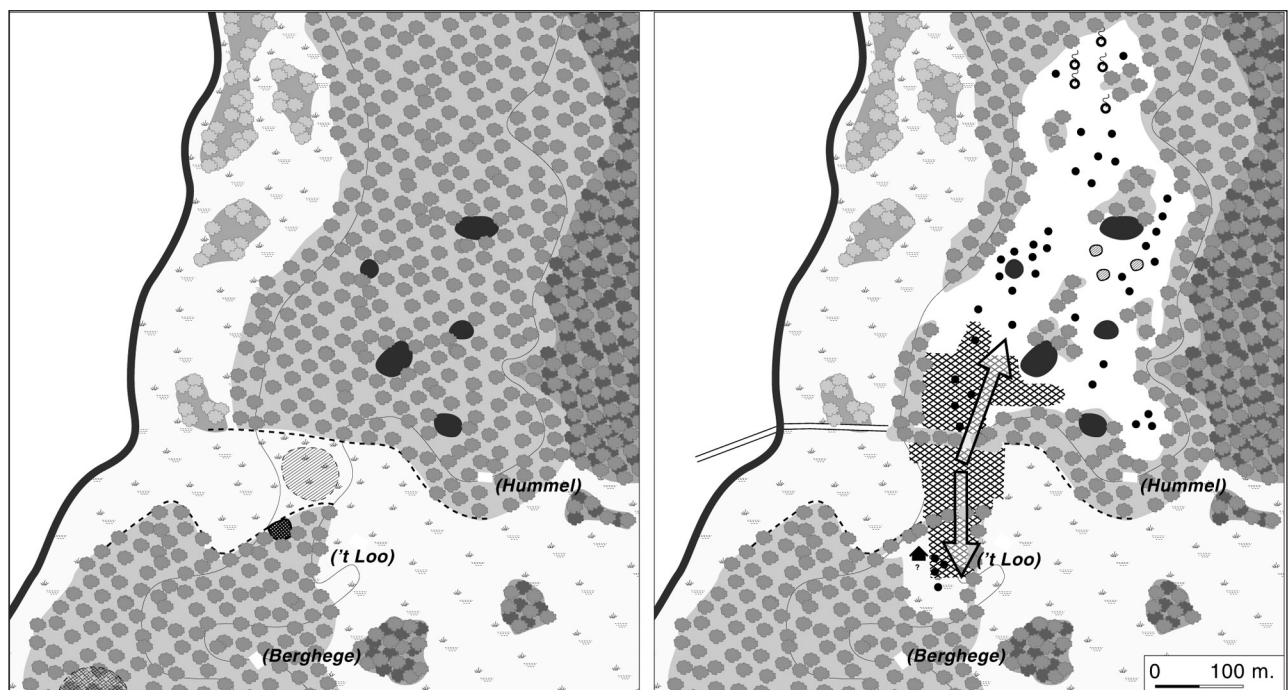


Figure 6: Zutphen-Looërenk. Shading in different greys indicates different types of woodland. Large black dots are small natural depressions and meres. Left panel: Natural woodland regeneration (c. 1st to 9th centuries AD) on a site that previously was settled open land (names indicate later Medieval farm sites). Right panel: Reclamation (c. 10th century) following charcoal production (c. 9th century). The kiln sites are schematically indicated as small black dots. Charcoal production and subsequent reclamation started (arrows) at a site ('t Loo') that had remained open after the settlement was abandoned because it was probably used as pasture land (after Groenewoudt, 2006). Further explanation in the text.

by reclamation, as the oldest indications for agricultural activity and settlement are contemporaneous with the charcoal production (11th–12th century; Brouwer, 2012). This may also have been the case at Almen-Asselerweg (unpublished data), where charcoal production has been dated to the 9th–10th century (1160± 30 BP: 780–970 cal AD), while the settlement is only slightly younger.

Case study of Anloo-Bosweg (northern Netherlands)

The most significant data on the alternation of deforestation and regeneration, and thus on woodland spatial dynamics at a local spatial scale, are from the Anloo-Bosweg site (Groenewoudt, 2005; Groenewoudt, 2007). Archaeological excavation revealed a total of 55 rectangular and round pit kilns. The total number of kilns within the approx. three-hectare research area was estimated at approx. 300. Moreover, the distribution pattern of the kilns suggests that many more kilns are present beyond the study area. Samples from nine pit kilns were subjected to archaeobotanical analysis. Most of the charcoal samples analysed consisted of oak; only one sample also contained some beech. The ¹⁴C dates obtained from 18 samples suggest two separate phases of charcoal production: 1) c. 200 BC–AD 200 and 2) c. AD 700–900 (**Figure 7**).

Scattered flint artefacts tentatively dated to the Neolithic indicate settlement activity in the area. Two radiocarbon dates (Late Bronze Age and Iron Age) are also associated with settlement. Remnants of an old plough soil are probably associated with the same late prehistoric settlement episodes. Prior to the excavations remains of a Celtic field, a levelled (undated) tumulus and some Iron Age finds were documented at the site (Jager, 1993). The earliest known reference to a woodland dates from AD 1314 (Smeenge, 2005); by the 17th century its extent was still fairly substantial (Elerie, 1993), and it still existed at the site of the excavation into the 18th century. Toponymic evidence suggests that, by this time, the woodland had degenerated to brushwood. The presence of a well-developed brown (cambic) podzolic soil (Dutch *moderpodzol*) at the site is an indication that deciduous woodland was present for a long period (Elerie, 1993). Given the fact that the local sandy soils are prone to degradation, any prolonged absence of woodland cover would almost certainly have led to soil degradation (leaching out of nutrients, acidification, and development of a *xeropodzol*). There was no indication of such development in the soil profiles studied.

Based on all the available data, the temporal sequence of land uses at the site has been reconstructed as follows:

Phase 1: c. 3000–2000 BC. Woodland was affected by human activity from at least the Neolithic period. Settlement traces suggest that small-scale woodland clearances occurred.

Phase 2: c. 2000–1000 BC. No evidence of human activity. It is assumed that regeneration into secondary woodland occurred. On a regional spatial scale, there is conclusive evidence (a high density of agricultural settlements) of extensive deforestation in the later Neolithic and, more especially, the Bronze Age.

Phase 3: c. 1000–400 BC. Between the Late Bronze Age and the Middle to Late Iron Age the area was settled, cultivated (Celtic field) and (largely) deforested.

Phase 4: c. 200 BC–AD 200. First charcoal production phase which indicates secondary woodland.

Phase 5: c. AD 200–700. Evidence for the period is lacking. Theoretically, the absence of charcoal burning may imply that woodland was absent. However, in light of the general population decline at this time (see above), it seems more likely that the site remained forested and that charcoal production ceased, a conclusion that was confirmed by the study of local soil profiles (see above).

Phase 6: c. AD 700–900. The second charcoal production phase testifies to the presence of woodland.

Phase 7: In AD 1314 a woodland was present (historical sources, see above). However, as the precise location and boundaries of the historical woodland are not known, we do not have any evidence that the excavated area was part of that woodland.

Phase 8: Woodland—by that time degenerated into brushwood—was present locally in the 17th century, but disappeared in the course of the 18th century.

On the basis of the interpretation above, it can be concluded that the site underwent at least three phases of deforestation and two phases of reforestation.

5. Conclusions

Woodland has always been a part of cultural landscapes. As a result of the dynamic interaction between humans and their environment, cultural landscapes and the woodland in them have always been subject to change. In the course of millennia these interactions formed the basis for the structure and dynamics of settlement patterns and, as a consequence, of woodland distribution in the landscape (**Figure 8**). Woodland regeneration on abandoned fields as demonstrated by the presence of charcoal kilns seems to have been common for a long time, and it was not unusual for this to occur several times at the same site.

Our results demonstrate that woodland regeneration and deforestation can be traced by a careful examination of the archaeological remains from charcoal production, provided such remains are systematically recorded, contextualized and subjected to meticulous dating, preferably ¹⁴C dating. Remains of charcoal kilns are also a useful source of information when attempting to reconstruct the occurrence and location (borders) of former woodlands. Optimum results are achieved for this purpose if charcoal kiln research is an integral part of an interdisciplinary landscape-historical approach. Evidently, absence of evidence (in this case of charcoal production) is not evidence of absence (in this case of woodland). Not all woodlands were exploited for the purpose of charcoal production.

Combining archaeological evidence on settlement activities and charcoal burning has shown that, in our research area, long-lasting settlement ‘micro-mobility’ occurred within a larger context of periodic settlement expansion and contraction over time demonstrated by

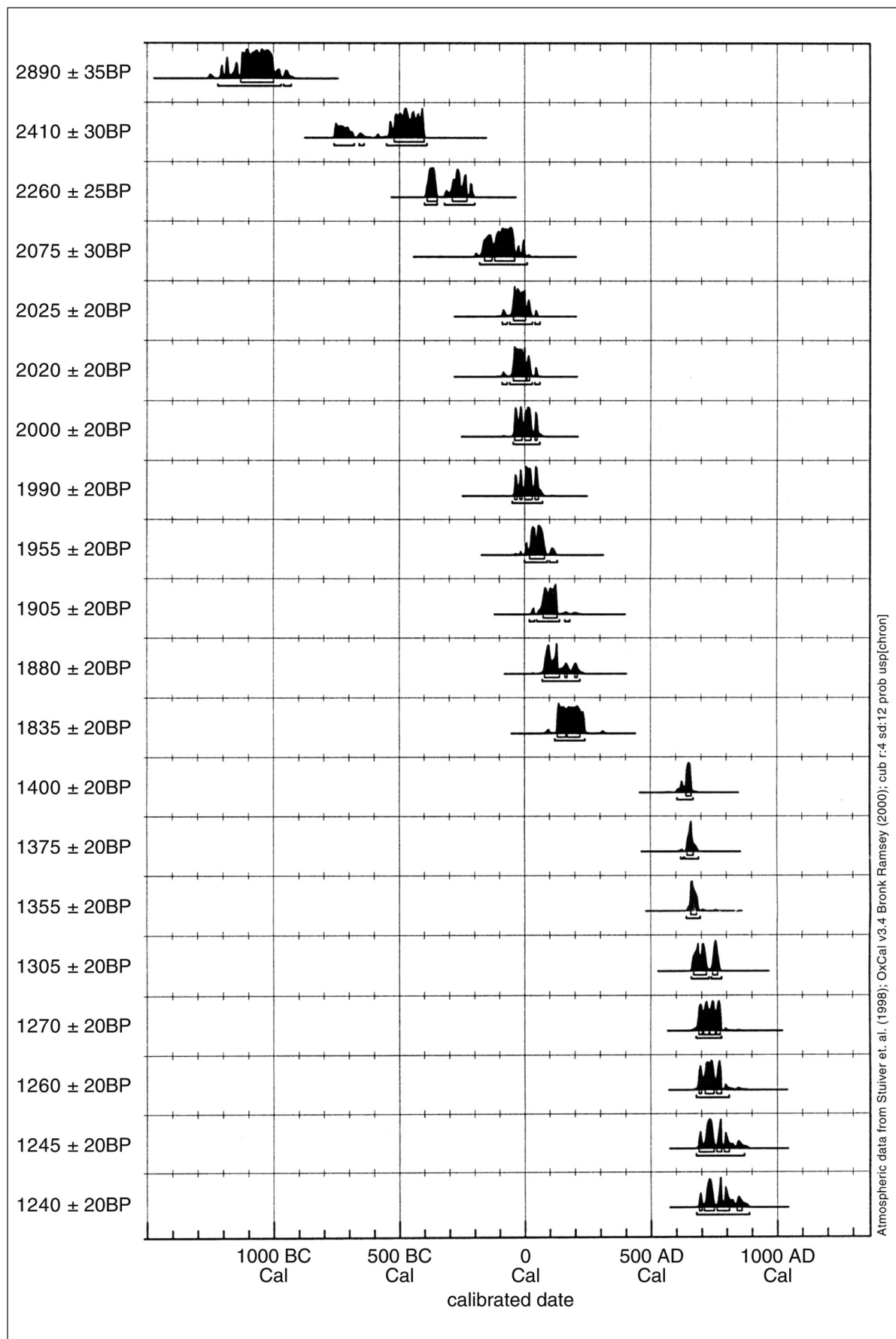


Figure 7: Anloo-Bosweg. Radiocarbon dates of charcoal from pit kilns interpreted as two phases of charcoal production using wood from secondary woodland. X-axis: age in calibrated years BC/AD with the probability distribution of the calibrated ^{14}C dates. Y-axis: ^{14}C dates in years BP. The two oldest dates (top) are related to settlement activity preceding charcoal production (and the local presence of woodland).

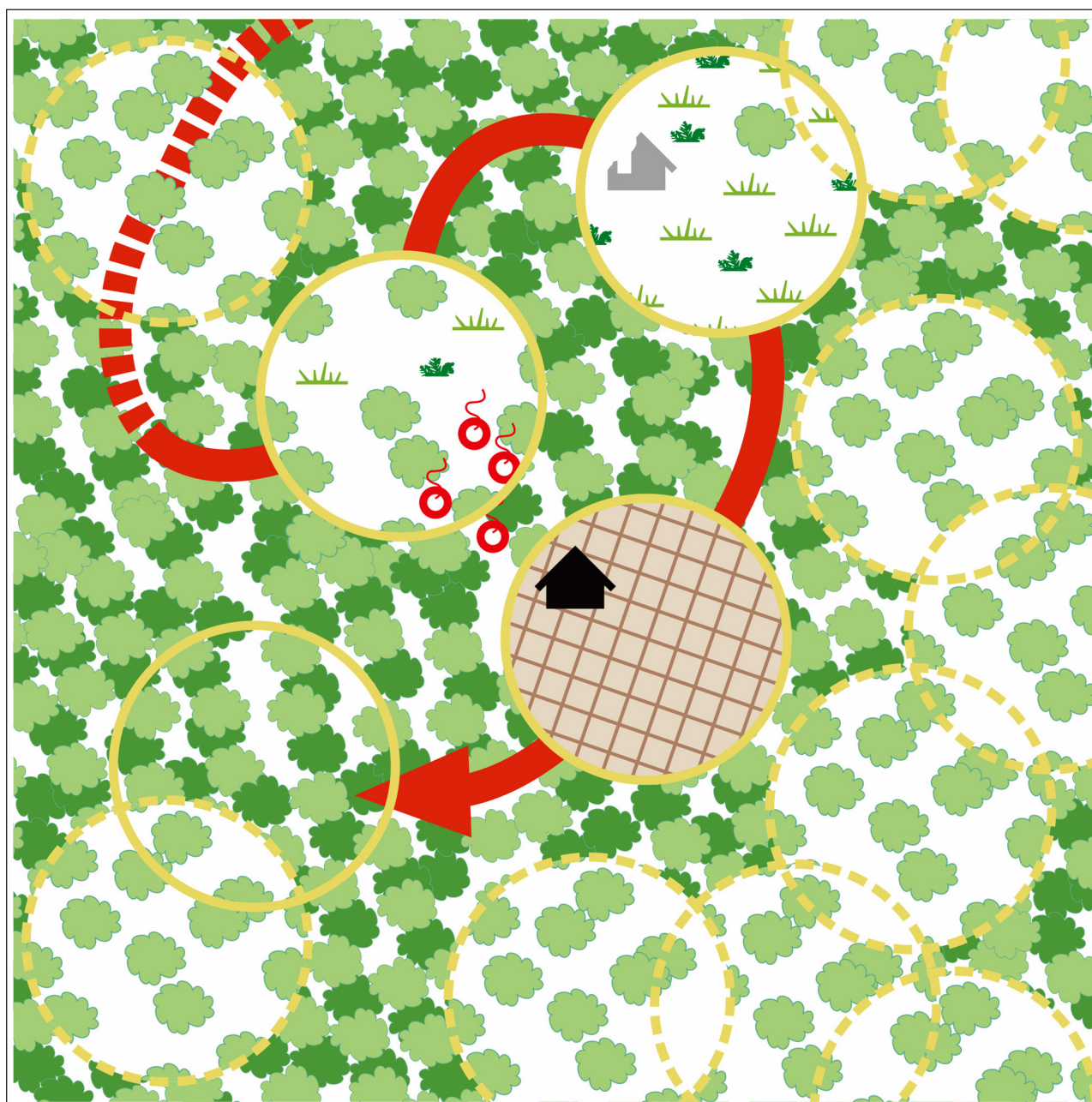


Figure 8: Proposed model of settlement mobility (“micro-mobility”) influencing the presence, type and composition of woodland and openness of woodland) on Pleistocene sandy soils in the Netherlands. Primeval or secondary woodland became increasingly open over time as a result of soil degradation and intensified land use. This model is based on the combination of data on settlement and charcoal production (red symbols). The establishment of settlements and agricultural land use cause deforestation. Circles represent (former) settlements and associated fields. Settlement relocation causes reforestation at former settlement sites. The local presence of secondary woodland is demonstrated by archaeological remains of charcoal kilns.

archaeological data on settlement and pollen records from long time series. Furthermore, a long-distance shift (‘macro-mobility’) took place during a brief period (the final centuries BC), leading to relocation of centres and peripheries at the regional spatial scale. Such major shifts explain why some areas characterised by late prehistoric field systems were reforested and remained wooded until today, as demonstrated for instance at Speulder- en Sprielderbosch (**Figure 3**). Woodland ‘mobility’ and change as defined in this paper was therefore brought about by a complex combination of three different types of settlement relocation: 1. expansion–contraction (periodic); 2. systemic

micro-mobility (structural) (**Figure 8**); 3. macro-mobility (incidental).

Competing Interests

The authors declare that they have no competing interests.

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